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An Evaluation of NASA's Program for Improving Aircraft Fuel Efficiency

Ad Hoc Committee on Aircraft Energy Efficiency Technology

Aeronautics and Space Engineering Board

Assembly of Engineering

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of NASA's Program for

Improving Aircraft Fuel Efficiency

A Report of the
Ad Hoc Committee on Aircraft Energy Efficiency Technology

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Assembly of Engineering
National Research Council

NATIONAL ACADEMY OF SCIENCES
Washington, D. C. 1980

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NOTICE

The project that is the subject of this report was approved by the Governing Board of the National Research Council, whose members are drawn from the Councils of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine. The members of the committee responsible for the report were chosen for their special competences and with regard for appropriate balance.

This report has been reviewed by a group other than the authors according to procedures approved by a Report Review Committee consisting of members of the National Academy of Sciences, the National Academy of Engineering, and the Institute of Medicine.

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PREFACE

This report is an evaluation of a program of research and technology development conducted by the National Aeronautics and Space Administration (NASA) to improve the fuel efficiency of transport aircraft. Known officially in NASA as the Aircraft Energy Efficiency (ACEE) program, it was initiated in 1975 as a ten-year effort in technological development, with the goal of advancing aircraft performance and increasing fuel economy.

NASA considers that advances in technology are possible, so that when applied the fuel required by commercial aircraft per unit of passenger travel should be reduced, the agency estimates, by 40 to 50 percent.* The technological opportunities for conserving fuel in air travel take many forms -- more fuel-efficient engines, lighter weight aircraft structures, and better aerodynamic designs.

NASA's ACEE program includes all of these elements. It recognizes that, contrary to some views that conservation is an all-or-nothing proposition, improvement in efficiency most often results from a continuous, incremental process based to a great extent on technology progress.

In 1979, with the program under way for nearly four years, NASA requested the National Research Council to perform an independent review of the ACEE program in order to gain an objective assessment of its achievements, its shortcomings, and its relevance to the aviation industry and the nation. Accordingly, the Research Council's Assembly of Engineering, through its Aeronautics and Space Engineering Board, established the ad hoc Committee on Aircraft

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*National Aeronautics and Space Administration. Aircraft Fuel Conservation Technology Task Force Report. Office of Aeronautics and Space Technology, Washington, D.C., September 10, 1975

Energy Efficiency Technology to conduct the review.

Specifically, the task of the ad hoc committee was to:

1. Review the elements of NASA's Aircraft Energy Efficiency program to determine technical progress, adequacy, timing, and significance of results; plans for the continuation of ongoing elements and for the initiation of future phases of multiphased elements to determine the appropriateness of the planned activities in the context of current and projected needs and the program's progress to date.

2. Recommend, if considered necessary, any changes in the objectives, approach, and technical content of the NASA Aircraft Energy Efficiency program, taking into account relevance, timeliness of results, and priorities; and changes needed in procedures or steps to overcome any problems or issues identified as preventing, or which may prevent implementation or incorporation of new technology in current or future aircraft.

The ad hoc committee held two two-day meetings at the National Academy of Sciences in Washington, D.C. At the first meeting, July 31 and August 1, 1979, the committee reviewed, through briefings and by discussions with NASA personnel, the program objectives and goals, program progress and results to date, and program plans for the future. At the second meeting, August 8 and 9, 1979, the committee received additional information in response to the questions raised during discussions at the first meeting, deliberated on the program, and developed the conclusions and recommendations found in this report.

The committee appreciates the careful preparation for these meetings by many NASA people, as well as their candid responses to questions. It is also grateful to Federal Aviation Administration staff members Albert P. Albrecht, Philip J. Akers, and John E. Reed for their assistance.

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INTRODUCTION

The implications of the Arab oil embargo of 1973-1974 had a forceful impact on most sectors of the nation's economy, including commercial aviation. The aviation industry had come of age in an era when energy prices were low and supplies seemed inexhaustible. With the quadrupling of the price of oil by late 1974 and increasing frequency of spot shortages, leading to government allocations of fuel, the need for conservation increased.

Deeply concerned about the situation, in January 1975, Senators Frank E. Moss and Barry Goldwater, then the principal members of the U.S. Senate Committee on Aeronautical and Space Sciences, asked the National Aeronautics and Space Administration (NASA) to establish a comprehensive program of aeronautical technology development that would make it possible to improve substantially the efficient use of aviation fuel and thereby help reduce the nation's dependence on oil and its vulnerability to excessive dependence on foreign supplies. Basic to NASA's technology development program, the Senate committee made it clear that greater fuel efficiency should be consistent with the national policy of minimizing adverse environmental effects of aircraft operation.

Responding to the Senate's charge, NASA prepared a plan for a 10-year program of technology development and initiated the program later in 1975 under the generic title of Aircraft Energy Efficiency (ACEE).

Central to the program are the technological opportunities for achieving significant savings in aviation fuel without degrading the environment. NASA's plan does not address nontechnical issues such as regulatory changes that might lead to reduced fuel requirements for the current air transport fleet. While the plan calls for NASA's traditional role of supporting research and technology to continue throughout the 10-year period, it did not call for NASA to develop prototype aircraft or engines. For certain technological elements, the demonstration of technology readiness requires experimental engine ground tests or proof-of-concept flight tests. The program allows NASA to do this, but the subsequent design, development, certification, and production phases are considered the responsibility of the airframe and aircraft engine manufacturers.

The program plan includes six major elements, three directed to evolutionary improvements in propulsion and aerodynamics. The other three elements - turboprops, laminar flow control, and composite primary aircraft structures - are technical features that are considerably different from those currently in use in long-range transport aircraft.

The six program elements, each bearing a number of subelements, are grouped in three categories:

Propulsion

- Energy Efficient Engine
- Advanced Turboprop
- Engine Components Improvement

Structures

- Composite Primary Aircraft Structures

Aerodynamics

- Energy Efficient Transport
- Laminar Flow Control

Following a review of all areas of aeronautical technology in 1975, a NASA task force defined the ACEE program in its report of September 10, 1975 and concluded that if an R&D program was pursued with commitment in a comprehensive and orderly way, the six program elements could lead to technological advances that might reduce the fuel used per unit of passenger travel by as much as 40 to 50 percent.

The Energy Efficient Engine element of the program is directed at establishing the technology base for achieving higher thermodynamic and propulsion efficiencies as well as improved durability in future engine designs. NASA estimates that such improvements will lower aircraft fuel consumption 15 to 20 percent below today's turbofan jet engines. This is to be achieved by the vigorous development of advanced components, which will be proof-tested in an experimental engine. The NASA program calls for the technology to be ready for use in new engine designs by 1983.

The Advanced Turboprop element derives from performance calculations that turbopropeller engines, with their high propulsion efficiency may save 15 to 20 percent more fuel than turbofans. When it was started, NASA's advanced turboprop program emphasized a single-point design with 80 percent propeller efficiency at the cruise speed of Mach 0.8 (about 530 mph), which was considered to be essential if the turboprop were to be accepted as a propulsion system for long-range commercial air transports. The NASA program includes

flight demonstrations of the turboprop.

The Engine Components Improvement program element seeks to provide components for use in new production of existing engines as well as in newly designed engines. Examples of such components are active clearance controls, mixers, and compliant seals. Some improved engine components are already in service and others are expected to be ready for use by 1981. This program activity also includes tests and evaluation of data from engines now in service to determine the causes of performance degradation over time.

Composite Primary Aircraft Structures involves the use of composite materials such as carbon or boron filaments arrayed in an epoxy polyimide or aluminum matrix in the primary structural components of aircraft and offer the potential of substantial reductions in aircraft weight. Such weight reductions translate into fuel savings on the order of 10-15 percent as compared with all-metal aircraft. If work on the composites goes according to plan, the new materials would be ready for use by industry in primary structures in the late 1980's.

The Energy Efficient Transport activity is directed at the evolutionary improvement of aerodynamic design and the development of active controls technology. NASA has been working closely with the manufacturing industry to provide the technological base for such advancements. Higher aspect-ratio wings with low sweep and improved airfoil sections have been designed based on improved computational methods and extensive wind-tunnel tests. Critical problems of active controls, which permit designs with reduced static-stability margins, are being addressed. This may lead to fuel savings on the order of 10-20 percent. Accordingly, the joint efforts by NASA and the industry have produced the technological bases for more fuel efficient aerodynamic designs. Such technologies will be applied to new designs as they are proven. It is possible that some aerodynamic changes could be incorporated in the redesign of successors to currently produced aircraft.

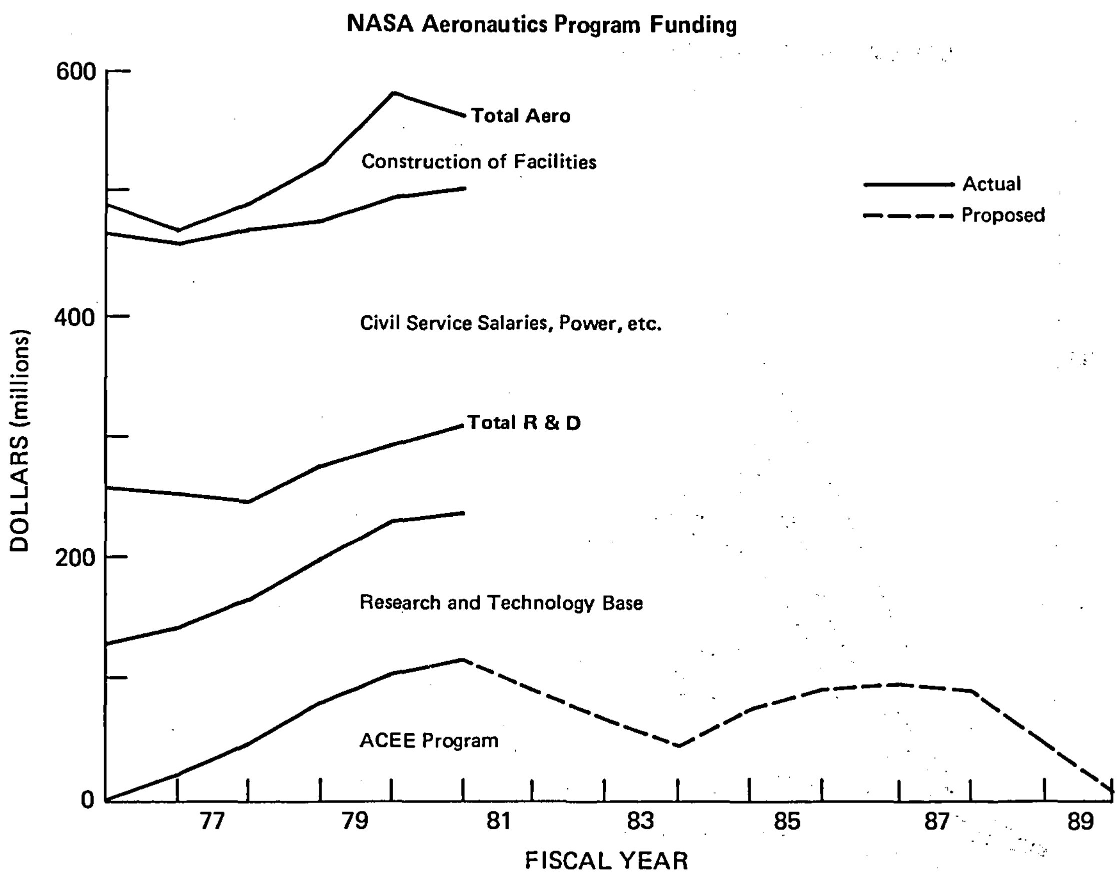
Laminar Flow Control is the element of the ACEE program with the greatest potential for saving fuel. During the cruise phase of subsonic transports, approximately one-half of the total drag is caused by skin friction, which is dependent on the nature of the boundary layer of the airflow on the aircraft surface -- i.e., whether the boundary layer is laminar or turbulent. By maintaining a laminar layer, skin friction will be reduced and, hence, fuel savings can be realized. Concepts for achieving such reductions in skin friction include the injection of air into the boundary layer through slots to accelerate it, removal of the boundary layer by suction, and use of compliant surfaces. Of the three concepts, boundary layer removal by suction is the only one considered by NASA to be a candidate for more intensive study at the present time. The work done to date on compliant surfaces appears to offer consider-

able promise for drag reduction through a favorable interaction between the turbulent pressure fluctuations in the boundary layer and a resilient or compliant coating on the surface.

The removal of the boundary layer by suction has been a tantalizing research area for some time. Previous efforts by the U.S. Air Force and the Northrop Corporation on the X-21 research aircraft had demonstrated that laminar flow could be obtained but did not answer questions of cost and weight increases that may accompany the technology. Nor did the Air Force or Northrop define the structural concepts and pumping systems, which must be reliable and maintainable. Advances in materials and structures now warrant another attempt to develop a practical system for laminar flow control. The current NASA program is phased to proceed into system development and flight test. Such a laminar flow control system could only be incorporated into a newly designed aircraft. If NASA's efforts are successful, they could make possible impressive fuel savings on the order of 30 percent.

The ACEE program is being conducted by the NASA Langley, Ames, Lewis, and Dryden Research Centers and includes both in-house and contracted activities.

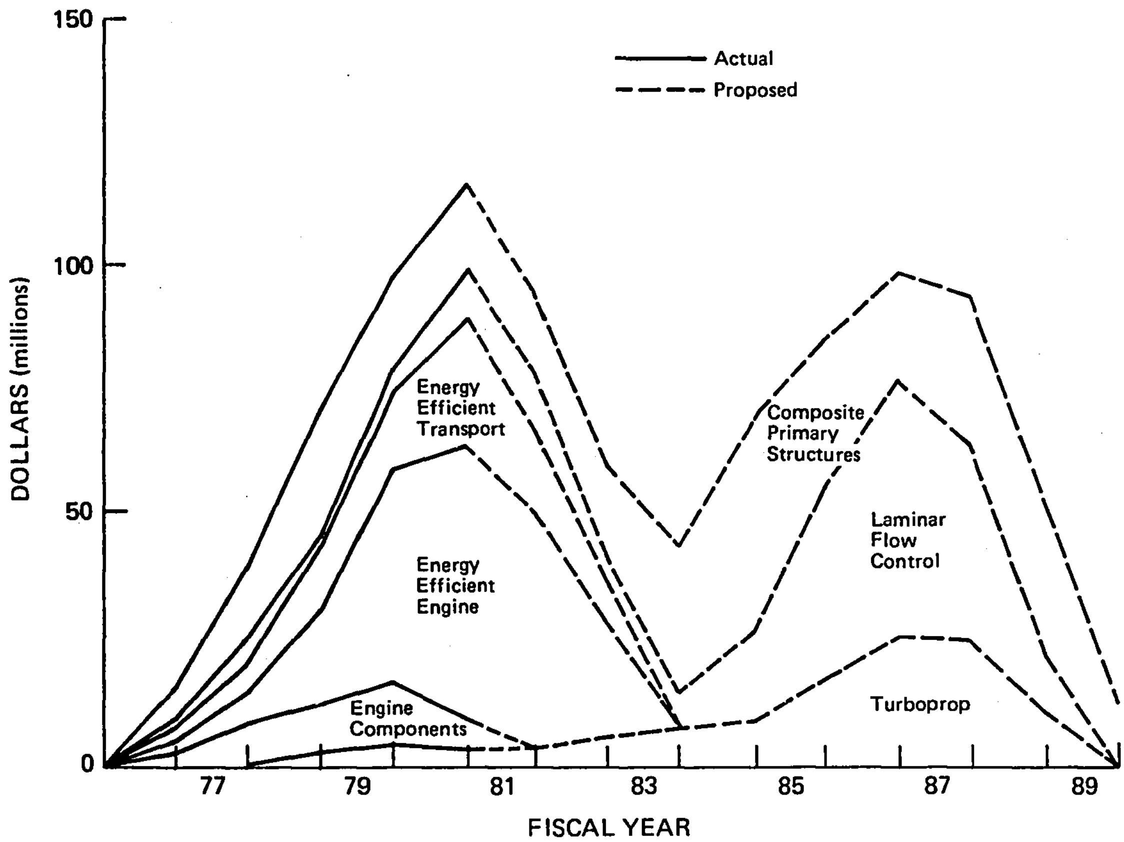
The funding for the program is displayed in Figures 1 and 2. Figure 1 shows the funding for the ACEE program relative to NASA's total program of research and technology in aeronautics from the initiation of the ACEE program through the fiscal year 1989. The plan for the ACEE program as presented to the committee is shown as a dashed line. The curve for the ACEE program funding is reproduced in Figure 2 with an expanded ordinate and shows the funding for the six program elements. Since its initiation in 1975, the program has undergone changes in the original plan. Some of the changes were required because of delays in the initiation of portions of the program, and in one case, the Energy Efficient Transport program element, the planned effort was augmented and the scope was increased to include active control technology. The changes have resulted in parts of the program being planned for completion in fiscal year 1989 rather than fiscal year 1985 as originally conceived. Parts of the Composite Primary Aircraft Structures element were delayed pending the outcome of a mandated investigation of the hazards of the release of carbon fibers in the event of a fire involving composite materials incorporating carbon fibers. The Advanced Turboprop program element was not approved for initiation until fiscal year 1978, and then only the first phase was approved. The succeeding phase is proposed to start in fiscal year 1981. In the case of the Laminar Flow Control element, funding is shown in fiscal years 1984-1989 for the conduct of flight tests. Work to date has indicated the need for more complete flight tests of details of the operational system than had originally been considered necessary.



SOURCE: NASA

FIGURE 1

NASA Aircraft Energy Efficiency Technology Program Funding



SOURCE: NASA

FIGURE 2

DISCUSSION AND RECOMMENDATIONS

Energy Efficient Engine

The committee considers that the Energy Efficient Engine program offers firm promise of technological advances for future turbofan engines that will provide increased fuel economy for the next generation of commercial aircraft engines. The balance of the program between component technology development and systems demonstration is judged thus far to be satisfactory. The committee views the program's goal as the aeromechanical development of advanced component technologies that should provide a base for design choices when new engines are committed for development in the 1980's. The program should not be considered a step in the development of specific engines or engine cores. For this reason the choice of size for the cores should not be considered critical, because scaling can be carried out with reasonable confidence at the time of engine design for development.

The committee concludes that the Energy Efficient Engine program, as structured, will make significant contributions to the technology of the next generation of commercial turbofan engines. The choices of cycle are in keeping with the ACEE objectives, and the component design selections by the contractors are sufficiently different to provide a reasonable range of possibilities. Even so, the committee holds that the allocation of additional time and resources to the integrated core low spool testing would yield valuable information on the validity of the advanced component data for application in engine design, and, therefore, it recommends that this work be supplemented in 1983 and later.

The committee finds the degree of technology advancement that is being attempted appropriate to the 1983 readiness date. In the design choice there are two considerations -- namely, the appropriateness of the thermodynamic cycle and bypass ratio and their mechanical implementation. The choice of a pressure ratio of about 40 and turbine inlet temperature near 2500°F at takeoff are judged to be appropriate for the next generation of commercial engines, as is the bypass ratio of

about 7 and the mixed exhaust. The higher pressure ratio and bypass ratio and the mixed exhaust are virtually dictated by the program goal of at least 12 percent fuel saving relative to current high-bypass engines, while the temperature is more or less determined by materials and durability requirements.

More room for choice exists in the implementation of the compression and expansion systems and in the combustor. Here the designs of the two contractors differ widely. The General Electric design employs a 22.6 pressure ratio high-compressor driven by a two-stage turbine, while the Pratt & Whitney design uses a 13.9 pressure ratio high-compressor driven by a single-stage turbine. In the G.E. design the compressor is considered the most advanced component; in the P&W design the turbine is the most advanced. While both use two zone combustors, the G.E. design is of the double-annular (parallel) type, while the P&W design places the main burner in series with the pilot burner. Similarly, there are large differences in the approach to the fan -- the G.E. design achieving the required high efficiency by a relatively low tip speed of 1200 ft/sec., and the P&W fan using hollow blades to eliminate the part span shroud and operating at 1500 ft/sec.

The differences in design approach are considered desirable, as they ensure the exploration of a wide range of possibilities in component design, some being more advanced and, hence, riskier than others.

The committee identifies no major omissions in NASA's planned coverage of the component technologies that are likely to be critical to the next generation of engines. The committee discussed the absence of a geared fan and a three-spool configuration from the program and agreed that this was appropriate.

The component choices are considered consistent with the 1983 design choice for an engine. However, the program is success-oriented, with little allowance made for problems should they arise and no allowance made for alternate component technology should any of the critical elements prove unfeasible. Thus, the predicted improvement in specific fuel consumption will be realized only if all the components meet NASA's objectives. It needs to be stated that the objectives are very ambitious when compared against the components now in service.

Advanced Turboprop

The committee finds that there is considerable promise for the application of advanced turboprop propulsion systems if the predicted performance improvements can be achieved in an integrated engine-propeller-aircraft system.

The advanced turboprop has a large potential for reducing fuel usage. Existing propellers become inefficient in flight at Mach

numbers above 0.65 to 0.70 because of the compressibility drag on the propeller tips. However, by using very thin blades, which is now possible with new advanced materials, and sweptback blade profiles, turboprops undergoing small-scale wind-tunnel tests have shown that propeller efficiencies of about 80 percent can be attained at a cruise Mach number of 0.8. To avoid the very large propeller diameters that would be required if conventional approaches were used with the high engine power required to fly at speeds approaching Mach 0.8, high solidity propellers of small diameter, called propfans, are being examined. The propfan has 8 to 10 very wide blades in order to absorb the power with a reasonable diameter. Studies of aircraft systems show that 80 percent propeller efficiency at Mach 0.8, combined with appropriate power plant and airframe weights, could lead to a fuel savings on the order of 15-20 percent as well as a potential reduction in operating costs of, perhaps, 5 percent compared to turbofan-powered aircraft with the same level of engine technology.

It is the judgment of the committee that if the propfan can be shown to obtain the hoped-for fuel and cost advantages in practical applications and if the problems of cabin noise and vibration can be overcome, the airlines will have to consider the propfan very seriously. Speeds for such applications could range from Mach 0.7 to Mach 0.8.

A major requirement is a thorough evaluation of the aeromechanical integrity of the propeller. This should include evaluations of the structural response caused by angle-of-attack and proximity to a swept wing as well as considerations of "one-engine-out" operations and reverse thrust. Damage tolerance, durability, and maintainability also need to be evaluated as well as assurance against blade separation. There are widely varying perceptions of the difficulty of the structural problem. Some committee members judge from past experience with propeller development that dealing with the propeller structure will be a costly development problem. Others are inclined to accept the view that the swept propeller can be built successfully using state-of-the-art construction techniques. The resolution of this issue is critical to the program.

A second major requirement is the demonstration that cabin noise and vibration can be kept to levels comparable to those in turbofan aircraft.

A flight test of a turboprop with flight-weight blades (not necessarily full scale but of sufficient scale to permit flight-weight structure) is considered essential for definitive evaluation of the structural, noise, and vibration questions. The test engine must be mounted so as to simulate realistic interference such as may occur with swept wings. A large scale propfan is required for the demonstration and validation of structural integrity, because there is considerable question about structural scaling capabilities, particularly with respect to the ability to extrapolate fatigue factors. The committee

recommends that, if possible, a meaningful wind-tunnel test program should be conducted to reduce risks before committing the turboprop to flight tests.

The committee concludes that aeroelasticity, durability, and damage-tolerance of the propfan blades, along with cabin noise and vibration, are the major technological questions. It also expresses concern about the reliability of a gear box for the high-power turbo-shaft engines. The committee recommends that work on advanced turboprops should move ahead and that NASA broaden the original cruise speed objective to encompass cruise speeds as low as Mach 0.7.

The advanced turboprop program also needs to be accelerated as much as possible within approximately the total funding planned for the program. The total funds programmed are considered adequate to address the issues identified, though the funds should be expended at a higher rate. This recommendation is based on the committie's observation that there could be a market right now for a proven advanced turboprop. The committee holds that the program is proceeding too slowly to contribute to this need.

Engine Components Improvement Program

The Engine Components Improvement program has been successful, and the committee recommends that NASA continually review possibilities for further improvements and support the ones that show promise. One aspect of the program, involving engine diagnostics, promises large dividends in understanding the reasons for in-service degradation of the efficiency of today's high-bypass turbofan engines. Such knowledge should lead to improvements in the future production of current engines and to minimize the problems encountered by engines utilizing the new technology obtained from the Energy Efficient Engine program. Thus, the committee endorses both the program as presently planned through 1980 and the proposed extension through 1985.

Composite Primary Aircraft Structures

The use of composite materials for aircraft structures offers wide opportunities for large reductions in aircraft weight. The potential redution in weight over aluminum structures is about 25 percent, as shown by the basic strength/density and stiffness/density characteristics of the material and by weight reductions actually achieved in such components as control surfaces and stabilizers. NASA's own research and NASA's support of industry research and development in design and manufacturing methods have accelerated the acquisition of knowledge of the characteristics and use of composite materials to the extent that the next major new transport aircraft, the Boeing 767, will introduce graphite/epoxy composites for most control surfaces.

Applications of composites to primary structures, such as heavily loaded wing structures and complex fuselages, are still off in the future, however. Many problems still remain to be solved, including crash-worthiness, fuel containment, lightning effects, durability, fire/smoke toxicity, inspectability, repairability, and large component manufacturing costs. Much more research, testing, and service experience is required before the industry will accept major composite structures with a high degree of confidence.

As far as the NASA program is concerned, the committee considers the composite primary aircraft structure element to be well planned. Accordingly, it strongly supports the work and the plans. The committee finds that composite materials are ready for application in secondary structures -- e.g., ailerons, flaps, rudders. Also, based on results to date, the committee considers the resin/matrix material to be at a stage at which aircraft manufacturers can tailor and develop it for use in primary structures. Therefore, the committee recommends that NASA move ahead with its planned large structures technology program, which includes wings and fuselages. Although the committee members all agree that a flight demonstration is desirable, some members believe it is not necessary and that long service experience with composite materials in secondary and medium primary structural elements, coupled with ground tests of large structures, will provide the needed confidence.

The committee recommends that NASA continue and augment, in parallel, its present research efforts on matrix materials with an aggressive program aimed at improving the structural properties of the composite materials and simplifying the manufacturing process.

Energy Efficient Transport

The Energy Efficient Transport portion of the ACEE program encompasses many elements, including aerodynamics, active controls, and integrated aircraft design concepts. The committee considers that this program has stimulated the study of many constructive ideas and in some cases accelerated the implementation of energy-saving design features in production aircraft. One outstanding aspect is active controls soon to be introduced on an advanced version of the L-1011 and now being considered for other future aircraft. Winglets, long-duct nacelles, high aspect ratio supercritical wings, and high lift systems are among the concepts studied.

Subsequent to its inception, NASA's work in active controls was augmented and emphasized, and the committee concurs in that decision. The committee recognizes that more possibilities for improvement can be exploited and recommends that NASA should continue this program beyond the present specific plan to the extent that it and the industry can develop promising additional concepts for improving air transport efficiency.

Laminar Flow Control

Laminar flow control is a technology with great potential for drag reduction and, hence, fuel savings. It possesses a long history of scientific and engineering research. However, the committee concludes that it has low probability for successful implementation in the commercial airline fleet. There is no doubt of the large reduction in drag that laminar boundary layer flow can bring. There is no doubt that properly shaped airfoils and appropriately distributed suction along the wing surface can produce laminar flow in wind-tunnels and in carefully run flights tests. The unsolved problems lie in the difficulty of producing wings of sufficient smoothness and uniform suction and in maintaining the quality of the wing surface in normal operations when clouds, insects, and dust are encountered.

NASA's ACEE program has identified several different and interesting wing-suction concepts, the most unique being the porous wing surface. After considering the various concepts, the committee concludes that practical feasibility, in terms of cost, weight, maintenance, inspection, and manufacturing has not been proven for any concept. The basic purpose of the ACEE program is to develop new technology for greater fuel efficiency so that it can be implemented in the U.S. commercial air transport industry in the foreseeable future. The probability of achieving this with laminar flow control is very small.

Because of the high technical risk, extended service flight tests will be required before new laminar flow technology is committed to production. Flight tests are costly, and the technology has not been developed to the point at which it is ready for flight testing. Moreover, the practical feasibility has not been proven in terms of maintenance, inspection, and manufacturing. The committee considers laminar flow control to be a research area of high potential but high risk. However, there is a high probability that obstacles to its implementation cannot be overcome in the foreseeable future. The committee considers the promised fuel savings from laminar flow control to be sufficient to warrant a continuing, concerted attack on the crucial issues of wing-surface structural development and the integrated system flight test of leading-edge systems. Because of concerns that past work has yielded few solutions to the basic problems, the committee recommends that the laminar flow control element of the ACEE program should be continued at a lower level of effort and assigned a lower priority.

The major barrier to the use of laminar flow control remains the maintenance of the laminar boundary layer in normal day-to-day aircraft operations. The program should center on the wing-surface structure and leading-edge systems. Studies of wing-surface design to improve

surface slots and perforations or porosity should be pursued. The object should be to develop structural systems with good performance, low cost, and easy maintainability and manufacturability. Maintaining clean, smooth, leading edges is a prime requirement. Several proposals to achieve insect and dust-free leading edges should be explored in flight tests. The successful demonstration of reliable, maintainable laminar flow over the leading edges would be an important milestone in aircraft engineering.

TECHNOLOGY IMPLEMENTATION

In response to the concerns expressed by Senators Moss and Goldwater in 1975, NASA initiated the ACEE program to develop and demonstrate the technology necessary to make possible fuel efficient aircraft. The purpose of the program is to advance the technology to the point at which manufacturers will be confident of specific performance at acceptable cost and customers will accept aircraft made with the new technology. Progress to this goal is enhanced in the ACEE program because most of the technology development is being conducted by the manufacturers under contract to NASA -- a process that involves the users of the new technology under development, which goes a long way toward effecting technology transfer and wider use.

The committee finds the technology development process under the ACEE program to be effective. Still, the implementation or use of the technology in production aircraft involves more than NASA, the manufacturers, and the airlines. Aircraft incorporating new technology must meet air-worthiness requirements established and certified by the Federal Aviation Administration (FAA). The committee recommends, therefore, that the FAA should be made aware of new technical developments early enough so that its technical personnel can be involved in the development to the extent necessary to understand the technology and be in a position to define certification requirements.

The committee concludes that the need exists for coordination between NASA and the FAA -- that discussion and cooperation will lead to NASA's better understanding of FAA's problems and needs for a data base for air-worthiness certification of new technology. Likewise, FAA could benefit from background knowledge of the new technology in promulgating any new regulations. The committee considers that cooperation is required to expedite the use and acceptance of new fuel saving technology at the earliest practical date.

Although not part of the ACEE program, the air traffic control system has a large impact on fuel usage. NASA's ACEE Task Force took cognizance of the possibilities for fuel savings in an improved air traffic control system when formulating the ACEE program, and in its

report dated September 10, 1975, it stated:

> "The Task Force searched for a technology development opportunity in operations or avionics. The hope was to permit more efficient operation of existing aircraft. However, the conclusion reached after extensive consideration was that no further improvements in on-board equipment were appropriate within the confines of the existing air traffic control systems. The airlines were confident that the FAA recognized this situation and was moving aggressively to improve the system. NASA is prepared to assist the FAA if any technology development tasks are to be delegated to it by the FAA in this area."*

The committee observes that the potential for fuel savings through an improved air traffic control system is significant. Moreover, NASA has a capability in avionics, flight controls, communications, sensors, satellites, and automated systems that can be brought to bear on the air traffic control problem. The committee, while recognizing that coordination and some joint effort already exists between the NASA and FAA, recommends that the management of both agencies discuss ways and means to work together to exploit more effectively the capabilities and responsibilities of each to develop improved air traffic control.

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*National Aeronautics and Space Administration. Aircraft Fuel Conservation Technology Task Force Report. Office of Aeronautics and Space Technology, Washington, D.C., September 10, 1975.

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